

Optics Development at the Brera Astronomical Observatory (OAB) for Constellation X

Part A

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SiC prototype optics for the WFXT project: obtained results

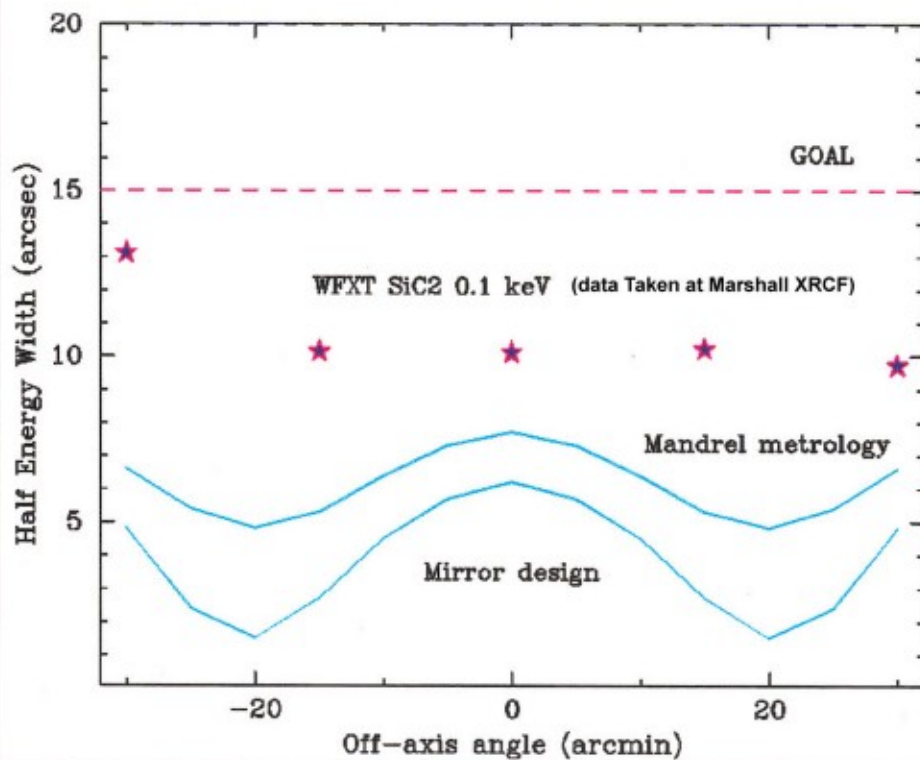
As a part of the WFXT (*Wide-Field X-ray Telescope*) project a number of prototype optics with polynomial profile has been realized (*the polynomial geometry guarantee a larger field compared to usual Wolter I structure*).

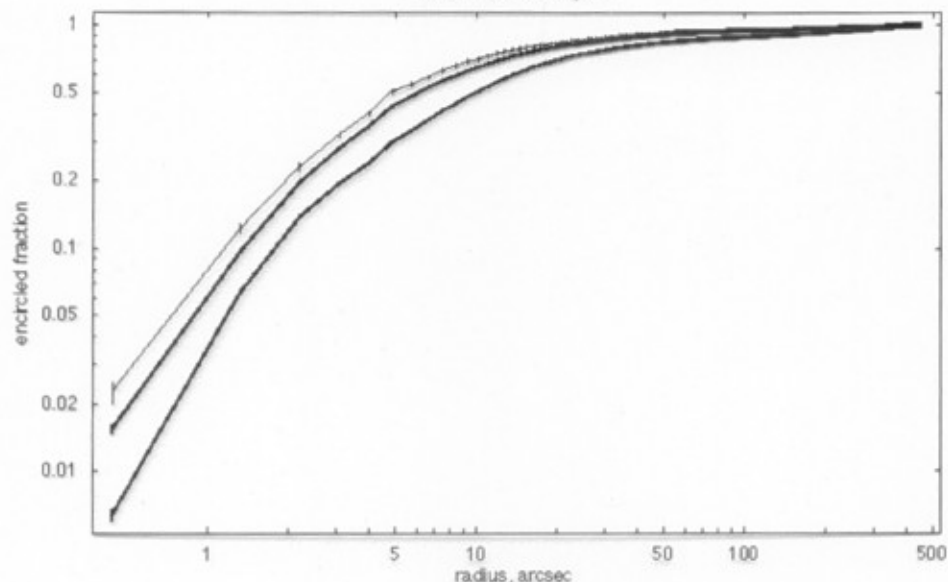
The matured experience with these mirror shells can be exploited also for the Constellation-X SXT development.

SiC-2 mirror Shell:

- Diameter = 60 cm
- Total height = 24 cm
- Wall thickness = 0.2 cm

X-ray imaging tests performed at the 518 m X-Ray Calibration Facility (XRCF) of the NASA Marshall Space Flight Center. The on-axis Half Power Diameter (HPD) are in very good agreement with the requirements for SXT.





Encircled Energy curves for Al-K (thick), C-K (medium), and Be-K (thin). In each case, we normalize to the total flux within a 15 arcmin diameter, corresponding to the HSI field-of-view.

Quadrant Half-Power Diameters (arcsec)

	region I	region II	region III
Be-K 0.108 keV	9.6	11.0	11.0
C-K 0.277 keV	12.2	13.8	14.7
Al-K 1.49 keV	20.0	26.2	28.6

Measured HPD vs. energy and mirror-surface region. This is the HPD with respect to a 15 arcmin field of view. The energy dependence indicates a surface roughness component which is larger for regions II and III.

Work in progress

- the 60 *cm* diameter WFXT mandrel has been re-polished: micro-roughness < 5 Å *rms*;
- the thickness of the shell SiC-1 has been made thinner (0.3 *cm* → 0.1 *cm*) at *Morton International* (Boston, MA). After the grinding process the shell seems to be still characterized by a good stiffness feature.
- Programmed work with the 60 *cm* WFXT re-polished mandrel:
 - Mirror shell replication using the SiC-2 (0.2 *cm* thick) to verify that the performances after the mandrel re-polishing;
 - Mirror shell replication using the SiC-1 (0.1 *cm* thick);
 - Mirror shell replication using an Alumina carrier 0.1 *cm* thick (**already available**).
- X-Ray tests to verify the optics performances;

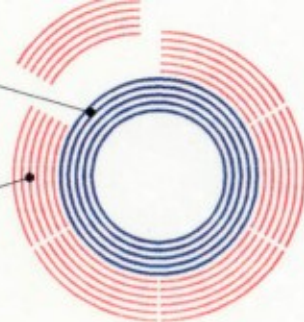
- Realization of mirror shell prototypes made of ceramic materials using the 50 *cm* diameter mandrels realized by C. Zeiss for the *Constellation-X* consortium;
- Feasibility study for an eventual design foreseeing part of the mirror shells made of segmented mirrors (the more external ones) while the more internal ones should remain based on the usual cylindrical close-structure.



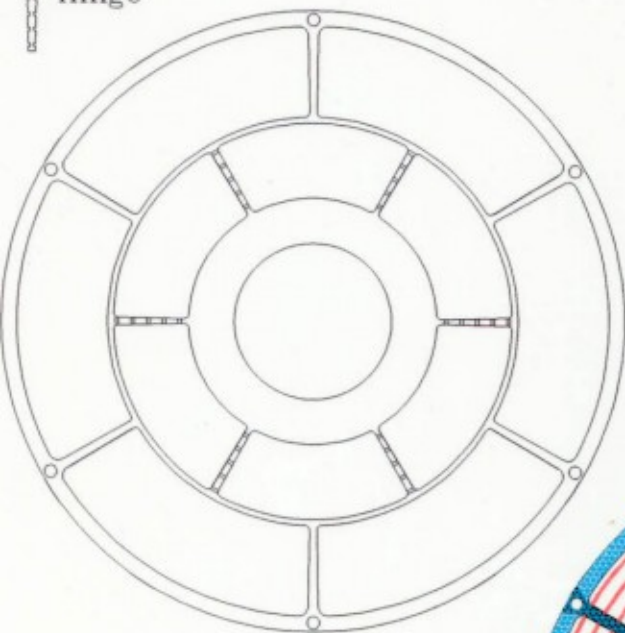
Full cylindrical
shells

HYBRID SYSTEM FOR SXT:
FULL CYLINDRICAL MIRROR SHELLS + SEGMENTED MIRRORS

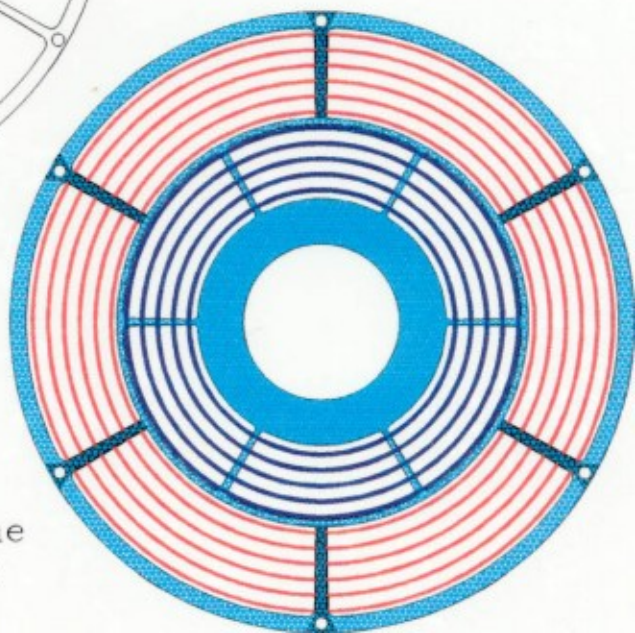
Segmented shells



Hinge



Spider



Cross section view of the
assembled Mirror-Shells

Part A:

Optics for the SXT (Spectroscopic X-ray Telescope)

- Ceramics materials for the SXT optics: advantages and technologies under development;
- Results obtained for the SiC prototype optics of the WFXT project;
- Work in progress and future activities;

Ceramic Materials for replicated X-ray optics

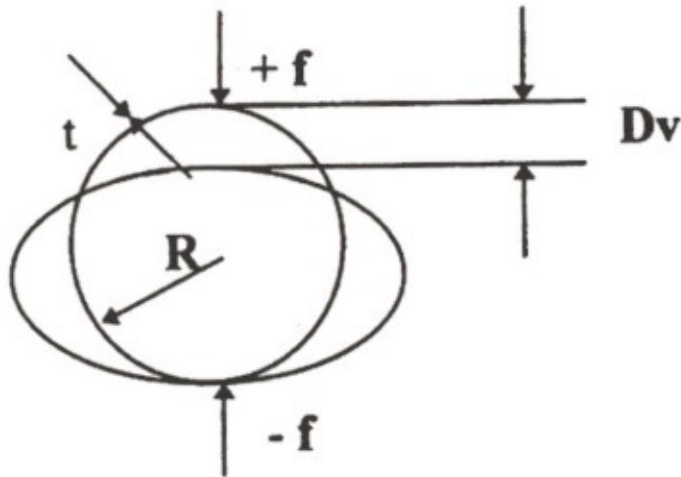
The high-throughput and good imaging capability mirrors with Au coating of the Beppo-SAX, JET-X and XMM X-ray telescopes have been realized exploiting the replication method by **Ni electroforming**. However for the SXT of the Constellation-X project the use of **ceramic materials** (SiC, Alumina,...) instead of Ni for the mirror support structure appears to be more convenient because:

- the lower density of ceramics materials can permit to better match the severe constraint for the SXT optics weight:

$$\rho_{\text{Ni}} = 8.87 \text{ g/cm}^3 \quad \rho_{\text{SiC}} = 3.2 \text{ g/cm}^3 \quad \rho_{\text{Alumina}} = 3.4 \text{ g/cm}^3$$

- the high elasticity and stiffness features of ceramic materials tends to avoid the plastic deformations taking place during the mandrel/mirror-shell separation phase of the replication process (absence of micro-yields);
- the low-density and mechanical parameters of ceramics are also more favorable against the risk of plastic deformations of large-diameter optics structure occurring after the separation;
- the resonance frequency of assembled ceramic mirror shells is much higher than for electroformed Ni mirrors.

DEFORMATION OF A CYLINDRICAL SHELL UNDER AN UNITARY LOAD



$$D_v \propto \frac{f R^3}{E t^3}$$

D_v = deformation f = unitary load R = shell radius
 E = elasticity modulus t = wall thickness K =

Material	Density (g/cm ³)	Elastic Modulus (G Pa)
Ni	8.87	150
Alumina	3.4	90
SiC	3.2	466

$$\Rightarrow D_v(\text{Alum}) = \frac{D_v(\text{Nickel})}{10}$$

$$\Rightarrow D_v(\text{SiC}) = \frac{D_v(\text{Nickel})}{63}$$

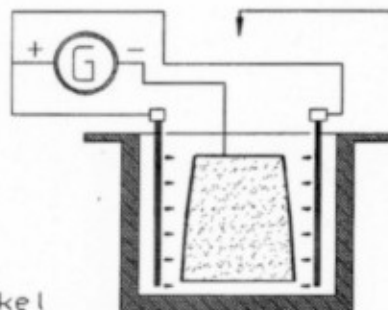
Superpolished
Mandrel



Gold
Evaporation



SIC
Carrier



Nickel
Electroforming

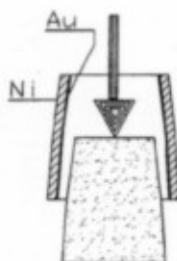
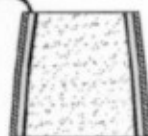


SIC carrier
+ Superpolished
Mandrel

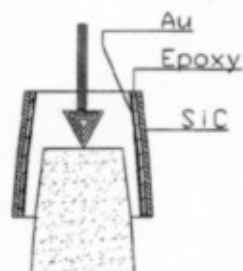
Mandrel with
Electroformed
mirror



Epoxy
Filling



Separation of
mirror from
mandrel by cooling

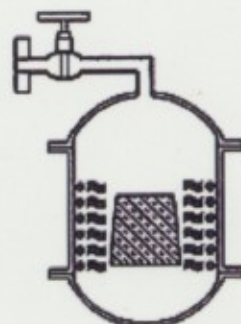


SiC CARRIER PRODUCTION PROCESS (CVD)

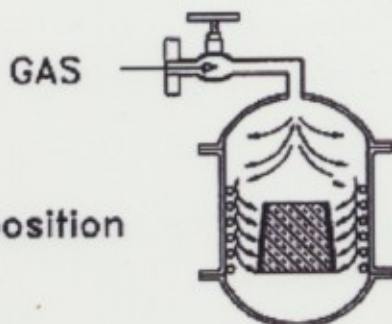
Graphite mandrel



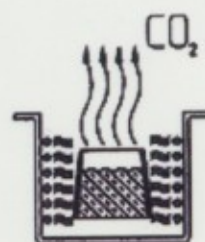
Heating to 1300 C°



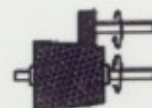
Silicon Carbide deposition



Graphite burn out

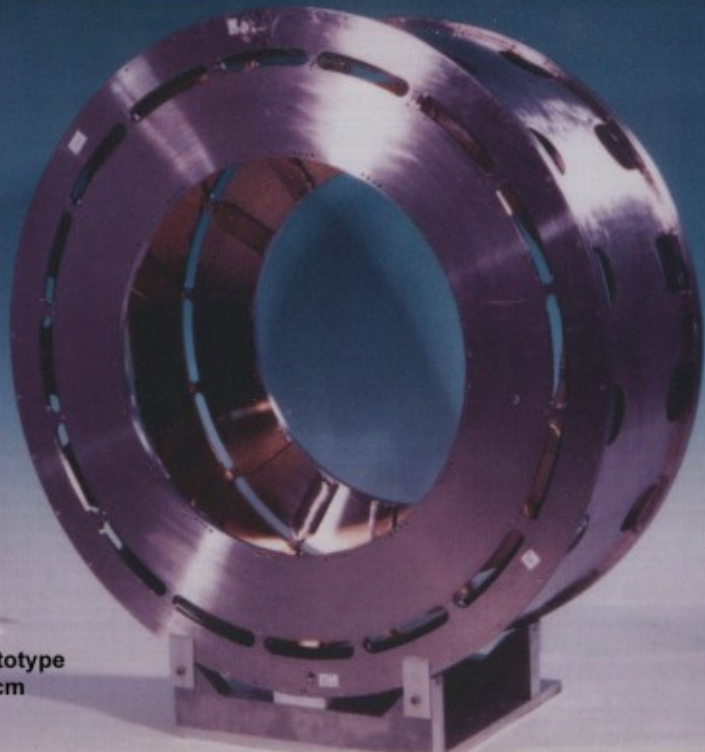


Grinding



Silicon Carbide (SiC) Carrier





NEXT SiC Optics
diameter = 60 cm

SiC Optics Prototype
Diameter = 60 cm

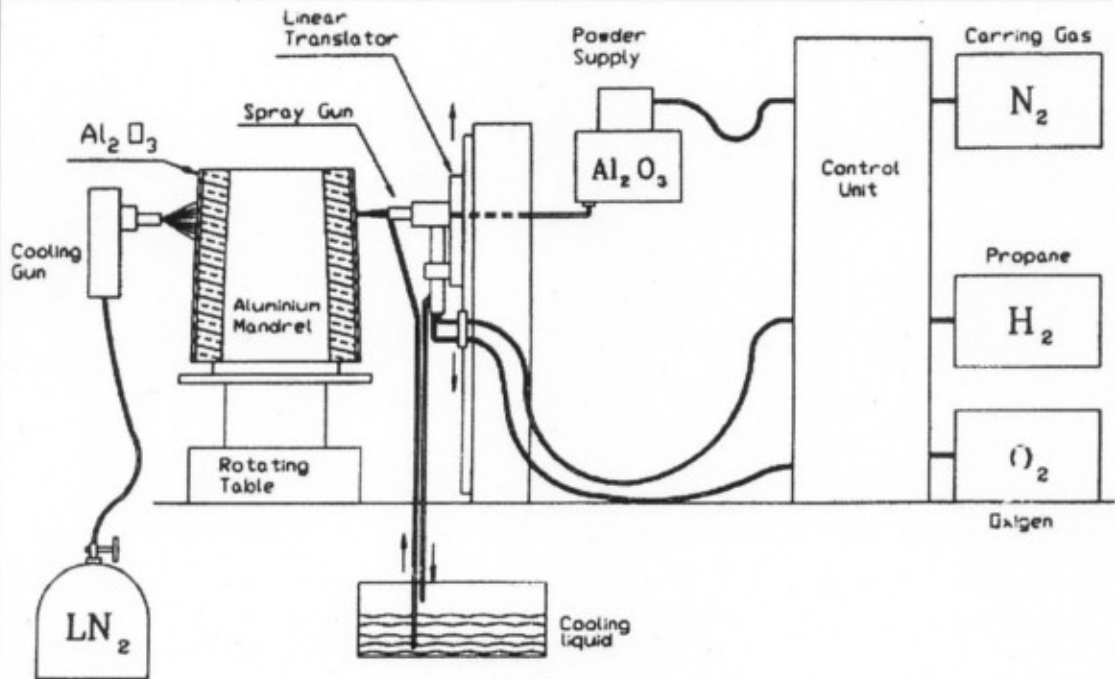
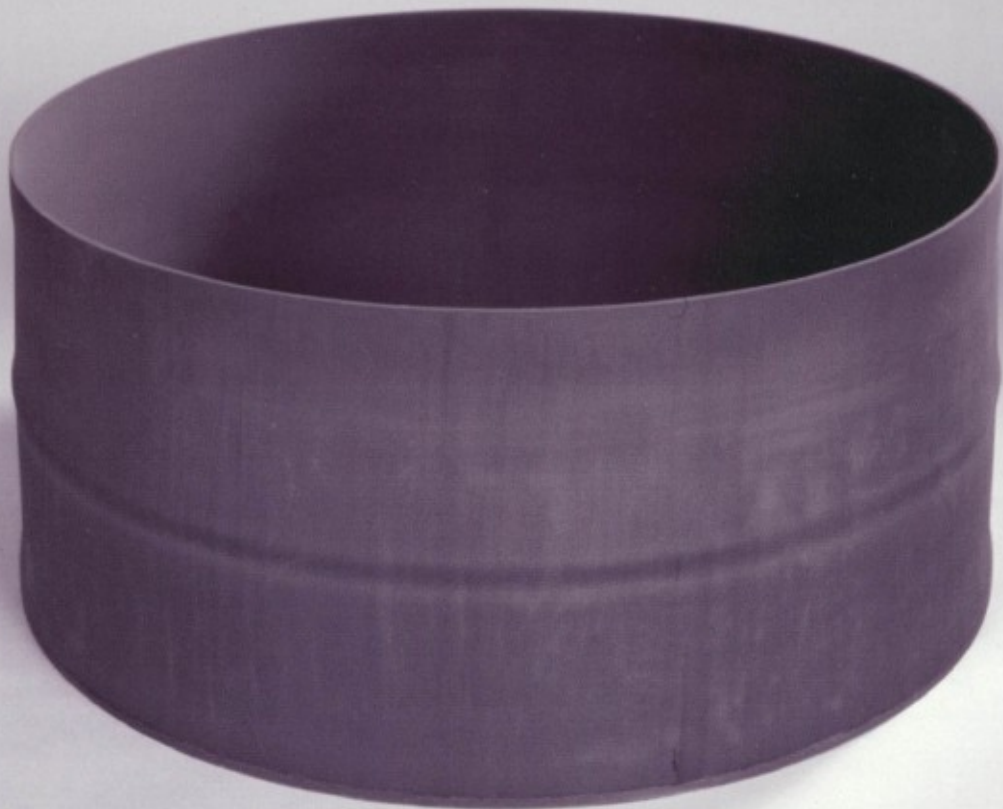


Figure 4. Plasma spray forming unit.



Manufacturing of an Alumina carrier (plasma spray process)



ALUMINA PROTOTYPE CARRIER -- diameter: 60 cm